

Parameter Analysis and Practical Application of a New Steel Damper

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Abstract. Steel damper is a new damper which is composed of steel pipe and curved steel bar. Because of simple production and good economic performance, It has good application prospect in large span structure, such as grid and reticulated shell. On the base of introducing the basic structure of steel damper and considering nonlinear properties of material, finite element software ANSYS was used to establish the calculation model. Influence to damper performance with parameters variation is analyzed in this article, then seismic performance of spherical reticulated shell installed with damper is researched. The results of study show that the steel damper is good in seismic performance, and has good enhancement effect to seismic performance of large span structure, such as grid and reticulated.

1. Introduction

Energy dissipation devices are usually installed in building structure. Structure damage in earthquake is reduced for seismic energy is dissipated by energy dissipation devices. Traditional energy damper has four types: viscous damper, viscoelastic damper, friction energy dissipation device and metal damper[1].

Metal damper is manufactured according to good hysteretic characteristics and large energy absorption in the elastic-plastic deformation process. Metal damper has good application prospect for the advantage of superior performance and simple manufacturing.

Type and performance of metal dampers was introduced detailed by wu cong xiao[2]. The types of metal damper are various, such as cone steel cantilever developed by Tyler[3], honeycomb damper designed by Yasushi Kurokawa[4], dual core section of unbonded brace developed by cai ke quan[5], lead viscoelastic damper put forwarded by zhou yun[6], zhou yun also introduced detailed seismic design of metallic dampers[7].

The researches on metal damper have never been stopped in recent years, such as new metallic variable friction damper developed by li hua[8]; partition type damper composed

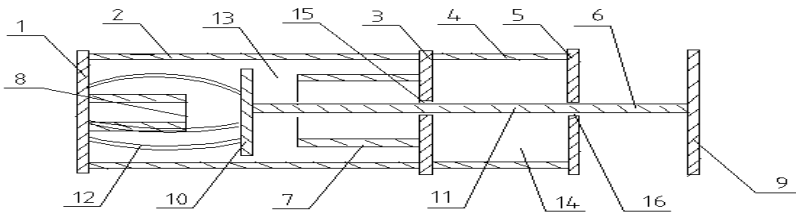
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of steel and lead developed by xin ya-jun[9]; buckling restrained brace developed by ning xiang-liang[10].

A new steel damper is put forward on the base of traditional dampers, calculation model is established by using ANSYS software, mechanical properties of this steel damper with different parameters are researched, then seismic performances of reticulated shell installed with steel damper have been analyzed.

2. Structure and Characteristic of Steel Damper

Steel damper is composed of bottom disk, left cabin, middle top plate ,right cabin , right top plate, pusher, left limiter and right limiter etc, as shown in Fig.1 .



1 bottom disk 2 left sleeve 3 middle top plate 4 right sleeve 5 right top plate 6 pusher 7 right limiter 8 left limiter 9 right actuator plate 10 left actuator plate 11 conduction bar 12 curved steel bar 13 left cabin 14 right cabin 15 middle top plate hole 16 right top plate hole

Fig. 1 Schematic diagram of steel damper

Both end of curved steel bar are fixed with bottom disk and left actuator plate separately. Pusher is composed of curved steel bar、left actuator plate、conduction bar and right actuator plate. Left actuator plate can move between left limiter and right limiter under axial load applied on right actuator plate. On the radial loads, steel damper can bear a certain bending moment through the touch between conduction bar and middle top plate and the touch between conduction bar and right top plate .

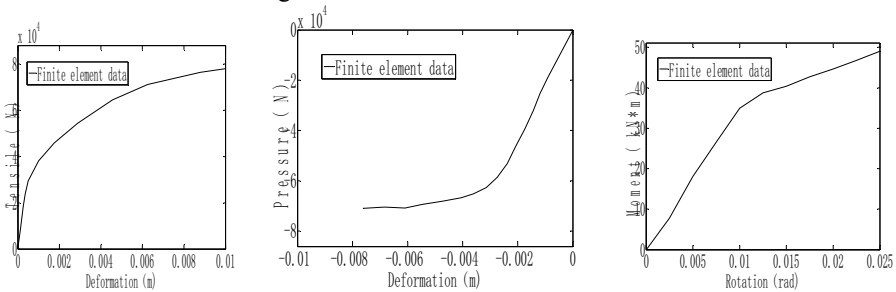
3. Establishment of Finite Element Model about Steel Damper

The yield strength of steel material is 345N/m², the constitutive relations of bilinear kinematic hardening elastic-plastic material model BKIN is used, Basinger effect is considered. The Poisson's ratio is 0.3, the density of the steel is 7850 kg/m³, the elastic modulus of materials is 206 GPa. Entities unit SOLID45 with the capacity of plasticity、large deformation and strain in ANSYS is selected to simulate each components of damper. Unit CONTA173 and TARGE170 are set between conduction bar, middle top plate and right top plate in order to simulate touch. Three curved steel bar whose diameter is 12mm and initial bending (the definition of initial bending is dividing the rise of steel bar by the length of horizontal projection) is 5% are uniform distributed, the diameter of conductor bar is 30mm, the distance between left limiter and right limiter is 20mm. The finite element model made in ANSYS are shown in Fig.2.



Fig.2 The finite element model of steel damper

By calculation, the curve of tension-displacement、pressure-displacement and moment-rotation are shown in Fig3.



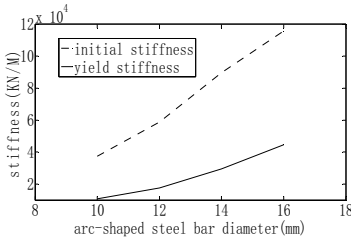
(a) Curve of tension-displacement (b) curve of pressure-displacement (c) curve of moment rotation

Fig 3 curve of load-deformation

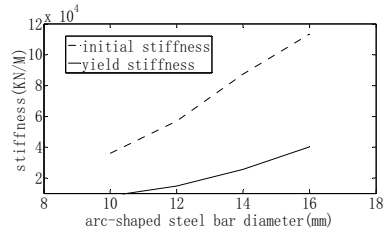
From the shape, the curve of tension-displacement、pressure-displacement and moment-rotation all can be simplified as two line model which include elastic stage and elastic-plastic stage. The main characteristic parameters of the model are initial stiffness of elastic stage and yield stiffness of elastic-plastic stage. Because the damper is composed of several components, and we can get the conclusion from Schematic diagram that the tension and pressure properties are mainly influenced by curved steel bar diameter、steel bar curved arc and the number of steel bar, and the bending performance is influenced mainly by conduction bar diameter and the thickness of middle top plate and right top plate . The influence to the performance of steel damper with the variation of these parameters are analyzed as follow.

4. Influence to Damper Performance with Parameter Variation

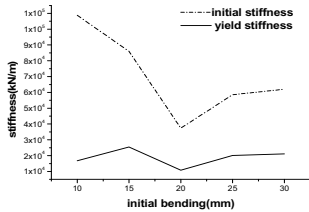
In order to analyze the performance influence to this damper with parameters variation, the other parameters are remained unchanged, the diameter of curved steel bar is set as 10mm,12mm,14mm,16mm; the initial bending of curved steel bar is set as 10%, 15%, 20%, 25%, 30% ;conductive rod diameter is set as 20mm, 25mm,30mm,35mm, the thickness of middle top plate and right top plate is 10mm,12mm,14mm,16mm。 The varied curves of initial stiffness and yield stiffness with the variation of parameters are shown in Fig 4.



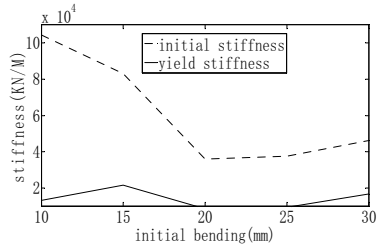
(a) influence to tensile stiffness with diameter variation



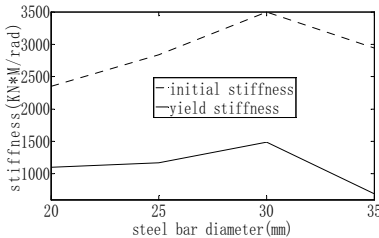
(b) influence to compressive stiffness with diameter variation



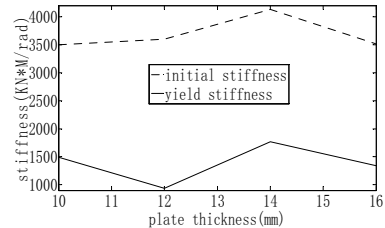
(c) influence to tensile stiffness with initial bending variation



(d) influence to compressive stiffness with initial bending variation



(e) influence to bending stiffness with conduction rod diameter variation



(f) influence to bending stiffness with steel plate thickness variation

Fig 4 influence to damper stiffness with parameter variation

From Fig4, we can get conclusion as follow:

(1) whether axial tension-displacement curve or axial compression-displacement curve, the initial stiffness and yield stiffness are improved with increasing of curved steel bar diameter ;

(2) the initial stiffness of axial tension-displacement curve and axial compression-displacement curve are decreased firstly, and then increased with increasing of curved steel bar initial bending, the yield stiffness of axial tension-displacement curve and axial compression-displacement curve are wavy development with curved steel bar initial bending changing, the yield stiffness reach the maximum when initial bending is 15% ;

(3) the initial stiffness and yield stiffness of bending angle curve are increased firstly and then decreased with increasing of conductive rod diameter, the initial stiffness and yield stiffness reach the maximum an the same time when conductive rod diameter is 30mm ;

(4) the initial stiffness of bending angle curve is increased firstly and then decreased with increasing of middle top plate thickness and right top plate thickness, yield stiffness is developed wavyly, the maximum value of initial stiffness and yield stiffness are gotten together when the thickness of steel plate is 14mm.

According to the upper analysis and processing difficulty level, the parameters of damper which are used in the following example analysis are chose as follow : diameter of curved steel bar is 12mm, initial bending of curved steel bar is 15%,conductive rod diameter is 30mm,middle top plate thickness and right top plate thickness are 14mm.

5. Seismic Analysis of Latticed Shell

In order to analyze the influence of damper to latticed shell seismic performance , A Skei Weed Le spherical reticulated shell is chosen as study object, the parameters of this shell are described as follow: the radius is 20m, span is 35m, the ratio of rise to span is 1:3.5, the number of main rib is 18, the number of ring is 6, the number of nod is 108, \varnothing 89x4mm circular tube is chose as weft bar and ring bar, \varnothing 79x4mm circular tube is chose as oblique rod. The final element model of latticed shell is shown in Fig5.

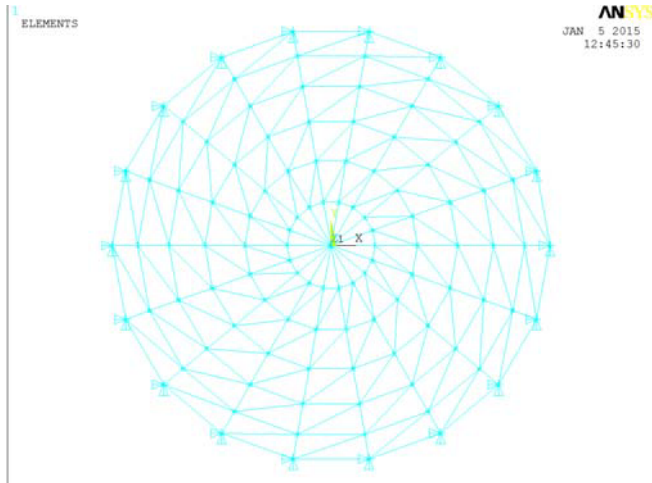


Fig 5 Finite element model of latticed shell

Three kinds of damper layout scheme are shown in Fig6 (dampers are expressed as bold line), dampers are decorated in ring direction in scheme 1, damper are decorated in radial direction in scheme 2, and dampers are in radial distribution in scheme 3.

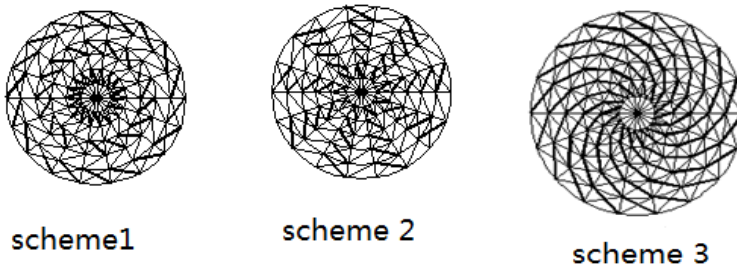


Fig 6 damper arrangement diagram

The structure performance on common earthquake of Tianjin wave、Tafe wave and EI-control wave are researched. Due to the limited space, we choose center point of shell as analysis object, the maximum displacement of center point are listed in table1.

Table 1 The Maximum Displacement Of Center Point Under Different Earthquake Wave(M)

	Tianjin wave	Taft wave	El-Centro wave
No damper	0.0346	0.0893	0.0487
scheme 1	0.0209	0.0391	0.0258
scheme 2	0.0198	0.0359	0.0238
scheme 3	0.0036	0.0084	0.0063

From the data in the table, we can see that the displacement is significantly reduced when damper is installed. In the three scheme, The optimal damping effect is scheme 3, damping effect of scheme 2 is better than scheme 1.

6. Conclusions

1) Energy dissipation capacity of curved steel bar is used by damper which has good application prospect in engineering.;

2)the initial stiffness and yield stiffness of axial tension-displacement curve and axial compression-displacement curve are improved with increasing of curved steel bar diameter;

3)the initial stiffness of axial tension-displacement curve and axial compression-displacement curve are decreased firstly, and then increased with increasing of curved steel bar initial bending, the yield stiffness of axial tension-displacement curve and axial compression-displacement curve are wavy development with changing of curved steel bar initial bending

4)the initial stiffness and yield stiffness of bending angle curve are increased firstly and then decrease with increasing of conductive rod diameter;

5)the initial stiffness of bending angle curve is increased firstly and then decreased with increasing of middle top plate thickness and right top plate thickness, yield stiffness is wavy development, the maximum value of yield stiffness and yield stiffness are got when thickness of of steel plate 14mm.

6) The seismic performance of shell can be improved when damper is installed. For Skei Weed Le spherical reticulated shell, the performance of shell with damper arrangement form shown in fig6(3) is the best, and the performance of shell with damper arrangement form shown in fig6(2) is better than that with damper arrangement form shown in fig6(1).

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